

ABSTRACT

A method of cleaning a semiconductor substrate conductive layer surface that can remove a residual organic material and a natural oxide satisfactorily and does not adversely affect a k value without damaging the side-wall insulation film of a via hole. A semiconductor device, including insulation films formed on the surface of a conductive layer of a semiconductor substrate and a via hole formed in an insulation film to partly expose the conductive layer, is carried into a reaction vessel, plasma including hydrogen is generated in the reaction vessel to clean the surface of the conductive layer at the bottom of the via hole, a residual organic material is decomposed and removed by ashing, and a copper oxide film on the surface of the conductive layer is reduced to Cu.

Please delete the paragraph at page 2, lines 4 and 5 in its entirety.

Please replace the paragraph at page 2, lines 7-18, with the following rewritten paragraph:

A fabrication process of this dual damascene structure includes a process for cleaning the surface of the conductive layer exposed through the bottom portion of the via hole. In many cases, etching residue of organic materials such as photoresist or the like lies on the surface of the conductive layer beneath the bottom portion of the via hole. Further, a native oxide film is inevitably formed on the surface of the conductive layer. For example, in case the conductive layer is copper, copper oxide (CuO) is formed on the surface of the copper. Such residual organic material or oxide causes a problem in that it causes an electric resistance of a via hole portion to increase.

Please replace the paragraph at page 2, lines 20-23, with the following rewritten paragraph:

~~Reference 1 discloses~~ It is known that the increase in the electric resistance of the via hole portion can be prevented by plasma processing a surface of a low-k film to form a detailed surface modification layer (see, for example, Japanese Patent Laid-Open application No. 2002-26121, Paragraph [0031] and Fig. 6).

Please replace the paragraph at page 2, line 25 to page 3, line 11, with the following rewritten paragraph:

Further, as a conventional method other than that disclosed in ~~Reference 1~~ the above-mentioned document, there is a method for cleaning the surface of the conductive layer

exposed through the bottom portion of the via hole. In this method, although the residual organic material is decomposed to be removed by injecting argon ions, since injecting the argon ions does not involve an ashing, residual organic material cannot be removed completely. Hence, the surface cannot be cleaned sufficiently. Further, native oxide cannot be removed. In addition, a damage is inflicted on an insulating film on a side wall of the via hole when the argon ions are injected, thus causing an adverse effect on the dielectric constant (k value).

Please replace the paragraph at page 6, line 11, with the following rewritten paragraph:

Fig. 7 depicts k values of the insulating film depending on flow rate ratios of He/H₂ gas;

Please replace the paragraph at page 6, line 12, with the following rewritten paragraph:

Fig. 8 describes k values of the insulating film depending on flow rate ratios of N₂/H₂ gas;

Please replace the paragraph at page 7, line 26 to page 8, line 7, with the following rewritten paragraph:

The slot plate 14 includes a circular conductive plate 141 made of a circular thin copper plate coated with ~~metal~~ gold or silver, and a plurality of T-shaped slits 142 are formed on the circular conductive plate 141. Further, the slots are formed radially in a direction of a radius, and gaps between the slits are preferably set to be $\lambda_g/2$ or λ_g , in which λ_g is the

wavelength of the microwave in the waveguide 132. An electric field distribution that is uniform in the processing chamber 11 is formed by the slits 142.

Please replace the paragraph at page 9, lines 9-22, with the following rewritten paragraph:

On outer parts of the walls of the processing chamber 11 is formed the coolant channel 24 in a manner that it surrounds the chamber. A gas supply source 130, a gas exhaust system ~~124~~ 120, a heater power supply 122 and the like are controlled by a controller 124, the controller including a CPU, memory storage media like a ROM and RAM, a hard disk, a CD-ROM driver and a transfer unit (not shown). By storing a software for performing the method for cleaning a surface of a conductive layer on the semiconductor substrate in accordance with the present invention in the hard disk or the ROM, or externally supplying the above-mentioned software by the CD-ROM or the like to transfer it to the RAM, the CPU in the controller ~~124~~ 120 carries out the cleaning method in accordance with the present invention.

Please replace the paragraph at page 11, lines 2-14, with the following rewritten paragraph:

It can be considered to use processing gases such as an Ar/O₂/He gas, an Ar/N₂/H₂ gas and an Ar/He/H₂ gas for removing the residual organic material 6 by generating plasma using the high density plasma processing apparatus 10. However, more preferably, by performing a plasma processing with a high density plasma of ~~10^{11} to $10^{13}/\text{cm}^2$~~ 10^{10} to $10^{13}/\text{cm}^3$ at a low electron temperature (0.7 eV to 2 eV) by the high density plasma processing apparatus 10 under an atmosphere of the Ar/He/H₂ gas to ash the residual organic material 6, the residual organic material 6 can be decomposed to be removed, and the copper oxide film 7 can be

reduced to copper without inflicting damage on the interlayer insulating films 2 and 3 or increasing the k value.

Please replace the paragraph at page 17, lines 1-20, with the following rewritten paragraph:

After vacuum pumping (S10), a substrate W of the dual damascene structure is transferred from another chamber (not shown) adjacent to the processing chamber 11 via the transfer port 133, and then set in the processing chamber 11 (S12). The gas supply source 130 supplies, typically, the Ar/He/H₂ gas into the processing chamber 11 (S14). Microwaves are propagated from the microwave generating source 128 into the processing chamber 11, thereby generating plasma (S16) (a high density plasma processing with a plasma density of 10^{11} to 10^{13} /cm³ at a low electron temperature (0.7 to 2 eV). By controlling the duration of the hydrogen-containing plasma generation, the residual organic material 6 on the side walls of the interlayer insulating films 2 and 3 is decomposed and removed by an ashing (S18). At the same time, the copper oxide film 7 on the surface of the conductive layer 1 exposed through a bottom portion of the via hole 4 is reduced to Cu. Thereafter, the plasma is stopped (S20), and then a vacuum pumping is performed (S22). Subsequently, the substrate W is taken out of the processing chamber 11 (S24).